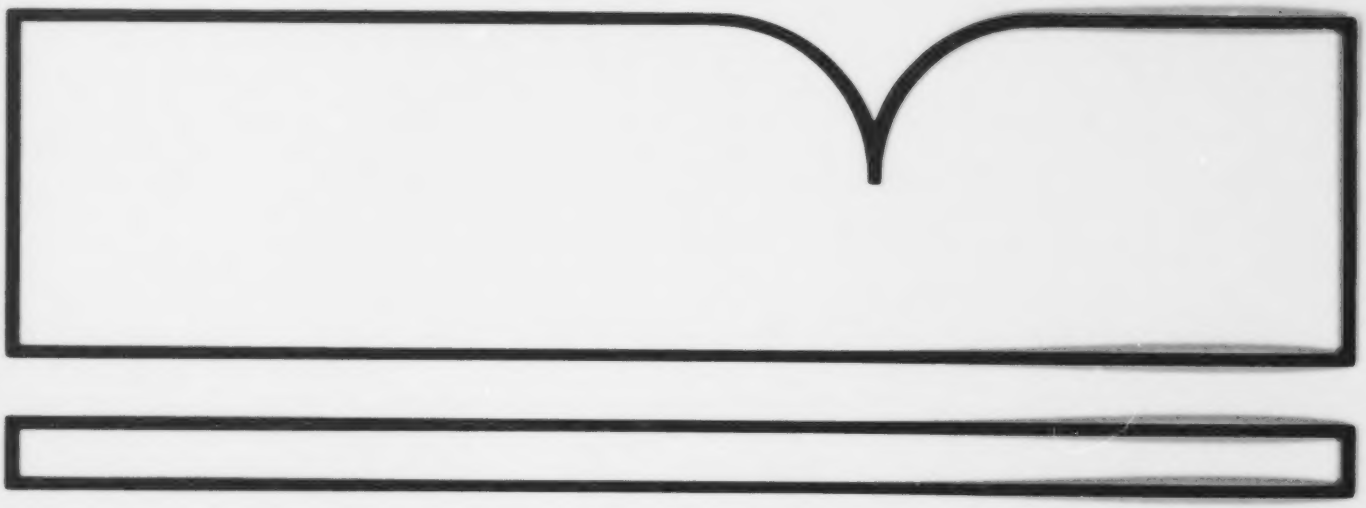
PB88-251780

SOx Out on a LIMB
(Limestone Injection Multistage Burner)

(U.S.) Environmental Protection Agency
Research Triangle Park, NC

1988



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TECHNICAL REPORT DATA
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1. REPORT NO. EPA/600/J-88/126	2.
3. REC	PB88-251780
4. TITLE AND SUBTITLE SO_x out on a LIMB (Journal Version)	5. REPORT DATE 1988
	6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Dennis C. Drehmel	8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS See Block 12.	10. PROGRAM ELEMENT NO.
	11. CONTRACT/GRANT NO. NA (Inhouse)
12. SPONSORING AGENCY NAME AND ADDRESS **EPA, Office of Research and Development** **Air and Energy Engineering Research Laboratory** **Research Triangle Park, NC 27711**	13. TYPE OF REPORT AND PERIOD COVERED Journal article; 11/87
	14. SPONSORING AGENCY CODE **EPA/600/13**

15. SUPPLEMENTARY NOTES Author Drehmel's mail drop is 4; his phone number is 919/541-7505. Published in Modern Power Systems, 5/88, pp. 73, 75, and 77.

16. ABSTRACT The paper describes the most recent results from the Limestone Injection Multistage Burner (LIMB) program, results from the wall-fired demonstration. Tests were conducted to determine the efficacy of commercial calcium hydroxide--Ca(CH)2--supplied by Marblehead Lime Co. and of calcium-lignosulfonate-modified Ca(OH)2. Performance of the modified sorbent was slightly better than that of the commercial sorbent. Both sorbents easily provided 50% capture of SO2 at a calcium to sulfur molar ratio of 2.0 or less, which is the goal of the LIMB program. The paper also lists the major conclusions from the LIMB program to date.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Pollution	Pollution Control	13B
Coal	Stationary Sources	21D
Burners	Limestone Injection Mul-	13A
Limestone	tistage Burners (LIMB)	08G
Combustion	Calcium Lignosulfonate	21B
Calcium Hydroxides		07B
Sulfur Dioxide		

18. DISTRIBUTION STATEMENT **Release to Public**	19. SECURITY CLASS *(This Report)* **Unclassified**	21. NO. OF PAGES 6
	20. SECURITY CLASS *(This page)* **Unclassified**	22. PRICE PC $9.95/MF $6.95

EPA Form 2220-1 (9-73)

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NATIONAL TECHNICAL
INFORMATION SERVICE
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SPRINGFIELD, VA. 22161

SO_x out on a LIMB

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EPA/600/J-88/126
JOURNAL ARTICLE

For several years, the EPA has sponsored control technology development in fields that showed promise of reductions in acid rain. One of these is LIMB (limestone injection, multistage burners). The object is to capture at least 50 per cent of the sulphur dioxide (SO_2) in a flue gas stream at a cost in terms of $/tonne competitive with FGD. LIMB will also lower nitrogen oxide (NO_x) emissions by 50 per cent with low NO_x technology in this case multistage burners.

The LIMB programme has reached the stage of full-scale demonstration. Research has concentrated on fundamentals, pilot and prototype scale tests, modelling, cost analysis, and demonstration.

Fundamentals have focused on the kinetics of potential LIMB reactions (eg. calcination and sulphation) and on properties of limestone and limestone products to identify and optimize properties providing high reactivity for SO_x capture.

Pilot and prototype scale tests have provided information on the effect of the furnace conditions on LIMB, on the effect of LIMB on furnace operations, and on the operation of the extant particulate collection device which is almost always an electrostatic precipitator (ESP).

Modelling is obviously used to analyse and extrapolate test data and to provide input to the fourth area (cost analysis) which compares LIMB to alternatives.

Demonstration provides the data necessary for generalization of the technology to the private sector.

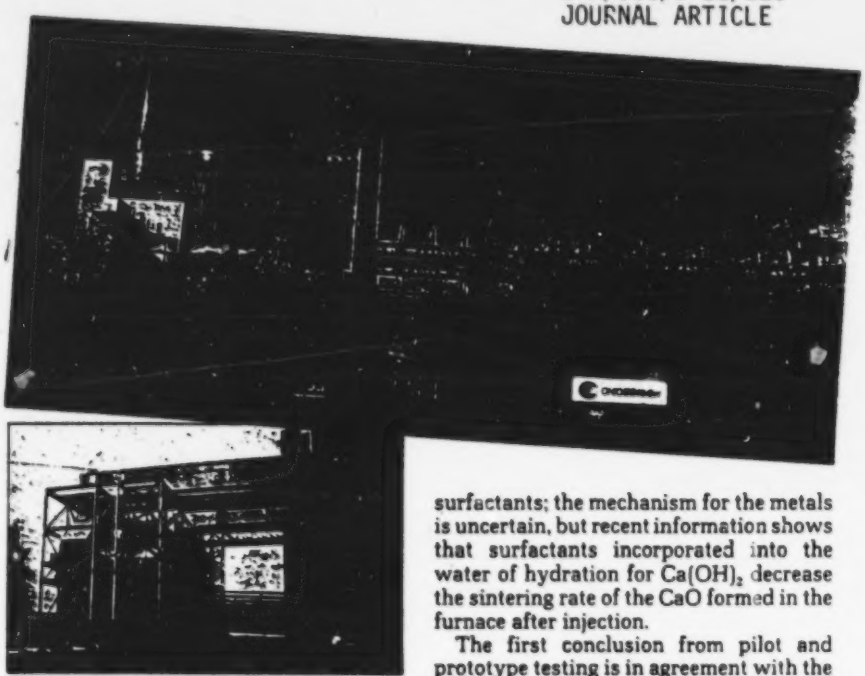
The LIMB programme calls for demonstration at two sites. One of these sites is a wall-fired power plant, and the other is a tangentially fired (T-fired) power plant. The wall-fired plant is described later.

The T-fired plant is a nominal 180 MWe constructed by Combustion Engineering and is located in Yorktown, Virginia. Because of the difference in firing systems, the flow patterns in wall- and T-fired boilers are significantly different. The flow pattern affects the mixing and the temperature history of injected sorbent particles. Thus, it is essential to test LIMB with these two types of firing systems which are the only two major types of firing systems for large scale utility boilers.

The most recent results from the LIMB programme are the results from the wall-fired demonstration. However, these results are preliminary and not optimized. Consequently, it is important to bear in mind important conclusions from the other parts of the LIMB programme which will aid in interpretation of the demonstration results.

These conclusions are discussed below.

The experimental section describes the system at the LIMB demonstration.



Edgewater unit at Lorain, Ohio, USA (top) and its electrostatic precipitator (above)

Background

Each of the LIMB activity areas has contributed important conclusions which explain decisions in the formulation of the LIMB demonstration and which may be useful in understanding early results recently obtained. Conclusions from the fundamental area are:

- Both calcium carbonate ($CaCO_3$) and calcium hydroxide ($Ca(OH)_2$) convert rapidly to calcium oxide (CaO) in furnace conditions; SO_2 capture is determined by reactivity of the CaO produced.
- The reactivity of CaO is determined by its surface area, particle size, and pore size distribution; CaO produced from $Ca(OH)_2$ has the more favourable surface area and pore size distribution for SO_2 capture.
- Loss of surface area of CaO, called sintering, renders high surface precalcines less effective than high surface area CaO formed from $Ca(OH)_2$ in the furnace.
- The reactivity of CaO may be enhanced by the addition of certain metal ions or surfactants; the mechanism for the metals is uncertain, but recent information shows that surfactants incorporated into the water of hydration for $Ca(OH)_2$ decrease the sintering rate of the CaO formed in the furnace after injection.

The first conclusion from pilot and prototype testing is in agreement with the results from fundamentals. The first and rest of these conclusions are as follows:

- $Ca(OH)_2$ is a superior SO_2 sorbent to either $CaCO_3$ (limestone) or CaO: the performance of $Ca(OH)_2$ can be enhanced by the addition of calcium lignosulphonate (a surfactant).
- The optimum injection temperature into a typical boiler furnace for $Ca(OH)_2$ is 1250°C; incorporation of calcium lignosulphonate allows injection at slightly higher temperatures without adverse effects.
- Deposits formed in the furnace in high temperature zones as a result of sorbent injection are soft and should be removable with normal or increased sootblowing typical of a power boiler furnace.
- Injection of $Ca(OH)_2$ increases the resistivity of the fly ash and decreases the efficiency of an ESP; the resistivity and efficiency can be restored by humidification which will also reactivate unused CaO for further SO_2 capture at low temperatures.
- The reactivity of commercial $Ca(OH)_2$ varies enough to affect attainment of SO_2 capture objectives; the most reactive $Ca(OH)_2$ in the area of the LIMB demonstration was found to be that supplied by Marblehead Lime Co.

Conclusions from the modelling and cost areas are:

- Heat transfer and mixing models are effective in predicting the location of optimum injection; the mixing model shows that poor injection is avoided only with great care and that poor mixing can cut overall SO_2 capture in half.

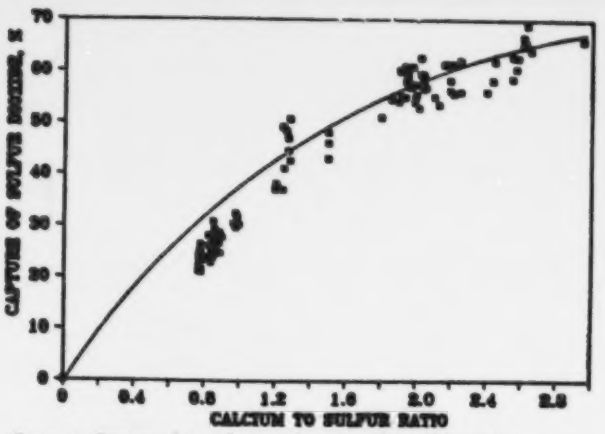


Figure 1. Capture data taken at elevation 181 at Edgewater

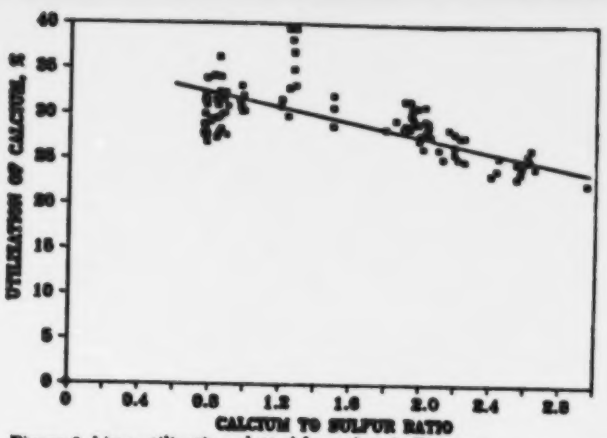


Figure 2. Lime utilization plotted from data in Figure 1

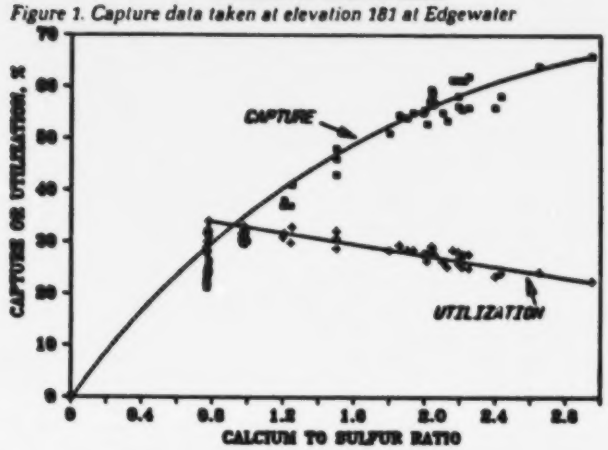


Figure 3. Data for Marblehead commercial sorbent

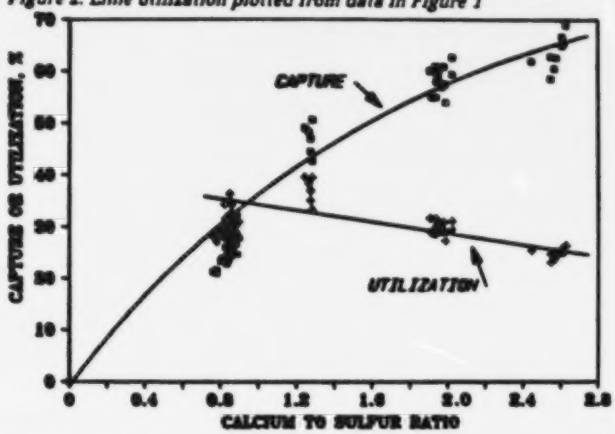


Figure 4. Data for lignosulphonate-modified sorbent

• The sulphation model shows that the good capture resulting from high surface area sorbents is available only at small particle sizes; large particle sizes increase pore diffusion and mask differences in basic reactivity.
• Because $Ca(OH)_2$ naturally has a much smaller particle size than $CaCO_3$, the cost to grind $CaCO_3$ to the same size would make it more expensive than $Ca(OH)_2$.
• Because LIMB is more operating cost and less capital cost intensive than wet or even dry FGD, LIMB competes well in older boilers or those with lower load factors.

Schedule of experiments

The site for the wall-fired LIMB demonstration is the Edgewater unit 4 of Ohio Edison Company, in Lorain, Ohio. The boiler is a nominal 105 MWe made by Babcock & Wilcox. It is a radiant, wall-fired, Carolina boiler burning eastern bituminous coal. It has been in operation since June 1, 1957.

The boiler has 12 burners fired from a single wall in a 3-column by 4-row array. The burners were B&W circular burners, recently changed to B&W XCL low NO_x burners for the "MB" (multistage burner) part of the LIMB program.

Particulates are collected by a 6-field Ladge Cottrell ESP which is only 4 years old. With respect to the "LI" (limestone injection) part of LIMB, the system for injection delivers sorbent to three levels in the boiler. These levels are elevations 181, 187, and 191 which have eight nozzles each in the front wall.

In addition, there are two nozzles on each side wall at elevation 187, and 90 cm from the front wall. Elevation 181 is slightly below and elevation 187 is slightly above the "nose" of the boiler. It is in this regime that the average injection temperature of 1250°C is available.

Obviously, the temperature varies across a horizontal cross section of the boiler because of heat transfer to the water cooled walls. In order to provide sorbent at these elevations, there are two air conveying systems consisting of Acrison feeders which drop sorbent to a star valve and down to the transport air jet.

The Acrison feeders are supplied by a small hopper or "day silo" inside the boiler house, and that hopper is in turn supplied by an external silo filled directly by truck.

Accurate determination of LIMB effectiveness is dependent on measurements of sorbent feed rate, outlet SO_2 concentration, and inlet SO_2 concentration as determined by coal feed rate and coal sulphur content. Sorbent feed rate was measured by the Acrison feeders noted above by virtue of their being differential weight loss feeders. Also, the inside hopper which feeds the Acrisons is equipped with load cells for an independent check on sorbent feed rate.

For the outlet SO_2 concentration, a continous emission monitor analyses the flue gas between the stack and the induced draught fan after the ESP. In this monitor, gas is extracted through a filter in the stack and another filter in a heated box before being drawn to a UV analyser. Both filters are hot (approximately 150°C) to avoid reactions of unused sorbent on the filter, and contamination is slight because the boiler's upstream (ESP) is highly efficient.

The coal feed rate is determined by computation from the boiler heat rate, using equations for the design of the Edgewater boiler which B&W considers proprietary. The coal/sulphur content is determined by sampling of the coal just before injection into the furnace. As noted above, coal feed rate and coal sulphur concentration are used to compute the inlet SO_2 concentration which is verified by the outlet monitor during periods without sorbent injection and well after any periods of sorbent injection.

Timetable

Test periods at Edgewater were:
• Low NO_x burner characterization with-

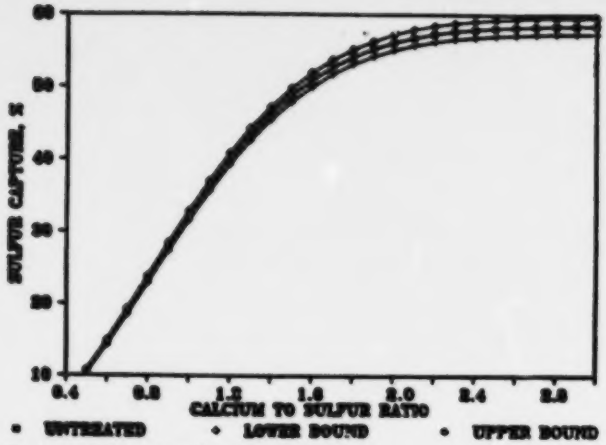


Figure 5. SO_2 capture for untreated sorbent

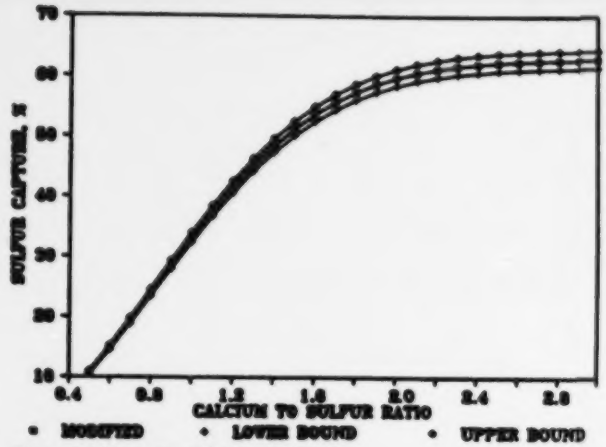


Figure 6. SO_2 capture for treated sorbent

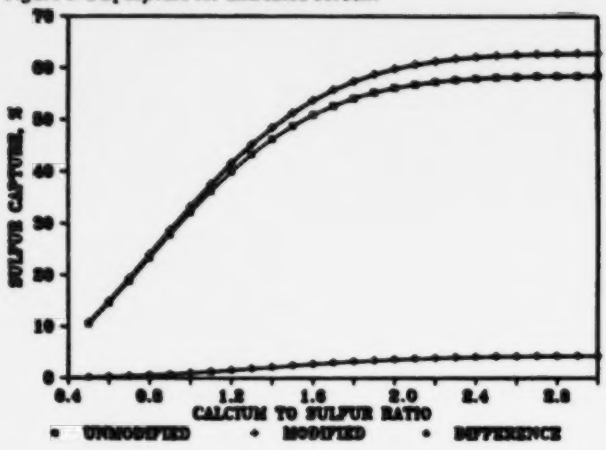


Figure 7. Average lines for treated and untreated sorbents

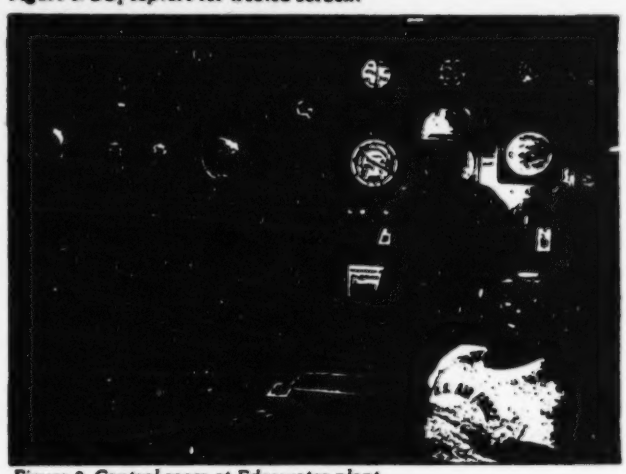


Figure 8. Control room at Edgewater plant

out limestone injection early July 1987.

- Shakedown of the system (primarily the feed system) from late July to late August 1987.
- SO_2 removal tests with commercial $Ca(OH)_2$ during September 1987; the commercial sorbent was supplied by Marblehead Lime Co. and injection was primarily at elevation 181.
- SO_2 removal tests with calcium lignosulphonate-modified $Ca(OH)_2$ during the last week of September 1987 before a regularly-scheduled outage. The modified sorbent was prepared by Marblehead Lime Co. from the same CaO used to make their normal commercial $Ca(OH)_2$. Injection was at elevation 181. Unlike previous tests in which all injections were with no tilt to the nozzle, the last test with the modified sorbent was with the nozzles tilted 15 degrees down.

All the elevation 181 capture data taken are shown in Figure 1 versus the calcium to sulphur molar ratio. By dividing the SO_2 capture by the calcium/sulphur ratio, the utilization of CaO is obtained and is plotted in Figure 2. Note that utilization decreases slightly with increasing calcium/sulphur ratio in approximately a linear fashion.

Figure 3 shows the data for the Marblehead commercial sorbent only, and Figure 4 the data for sorbent modified with calcium lignosulphonate. These two figures present both the SO_2 capture and the CaO utilization as a function of the Ca/S ratio.

Results considered

Statistical analysis of the data provides a useful interpretation of the results of the Edgewater demonstration to date.

Figures 5 and 6 show the predicted SO_2 captures for untreated and treated sorbents, respectively. The middle line is the average prediction, and the outside lines show the prediction for upper and lower bounds as defined by two standard deviations from the average. These figures show that LIMB easily meets its objective of 50 per cent sulphur capture at a Ca/S ratio of 2.0 or less. The average lines for both untreated and treated sorbents are shown together in Figure 7.

Comparison of the lower bound of the treated sorbent with the upper bound of the untreated sorbent shows a positive difference at Ca/S ratios above 1.5.

Unfortunately, there was insufficient time for testing before the scheduled outage to even begin optimization for either untreated or treated sorbent; consequently, it is too early to draw any conclusions about the ultimate difference between these two sorbents.

After the scheduled outage, a full scale humidifier will be brought on line. As noted above, the humidifier lowers the resistivity of the fly ash to the benefit of the ESP and reactivates unused lime for further SO_2 capture at low temperatures.

Based on pilot plant experience, it is expected that an extra 10-15 per cent of SO_2 will be captured at low temperature. This would raise total capture to 65-70 per cent at a Ca/S ratio of 2.0.

Once the humidifier is in continuous operation, the system will be tested in a parametric array which will identify optimum conditions for capture with and without treatment of the $Ca(OH)_2$ with calcium lignosulphonate. During this period, the ultimate comparison between treated and untreated sorbents will be determined. Also decided will be the optimum injection elevation, angle, and velocity.

Once these have been established, the injection system can begin long-term testing to determine the effect of injection on boiler operation. Meanwhile, conditions for humidification will be varied to optimize the low temperature SO_2 capture.

Eventually, all systems will be configured at their optimum operation for SO_2 capture to establish reliability of the LIMB-with-humidification process. □

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